

## Nuclear Science Division Newsletter

2013/2

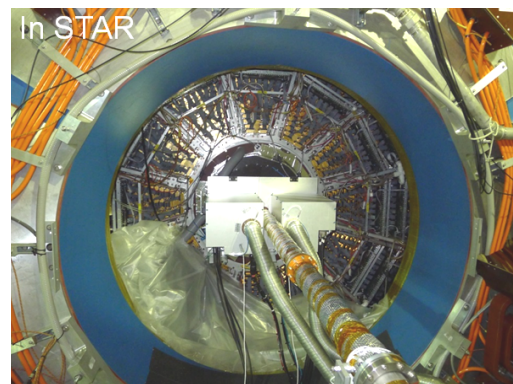
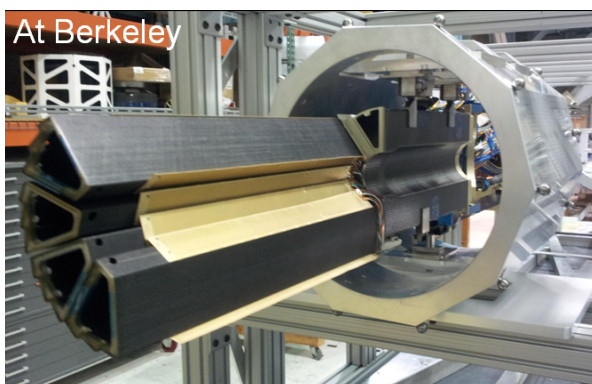
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### The STAR Heavy Flavor Tracker: First light for the PIXEL detector

The STAR Heavy Flavor Tracker (HFT) is a high-resolution silicon vertex tracking device that is being developed for the STAR experiment at RHIC by the RNC group in the Nuclear Science Division at LBNL. The HFT is a four-layer Si tracker that is optimized for the reconstruction of particles that are produced in relativistic nuclear collisions and decay between 50 and 500 microns from the interaction point. In particular, the HFT will track mesons that contain heavy flavors (charm and beauty) and it will explore their flow and energy loss in the dense medium of quarks and gluons created by the collisions.

The first two layers of the HFT is the PIXEL detector, built with monolithic active pixel sensors (MAPS) for a total of 360 million pixels in the final assembly. Each chip contains 900,000 pixels plus active logic and analog-to-digital conversion circuits. The expected pointing resolution is 30 microns for 1 GeV particles.

On May 8, three sectors of MAPS Sensors (120 Million pixels) were installed at STAR (see figures). The most remarkable fact about the engineering run is that these three sectors were installed in STAR in less than 12 hours. It is stable to ~20 microns and was aligned and matched with tracks from the remainder of the STAR detector in less than 3 weeks of operation. These accomplishments from a world record for installing a Si detector in an active collider detector. It is also the very first application of MAPS sensors in a collider environment.



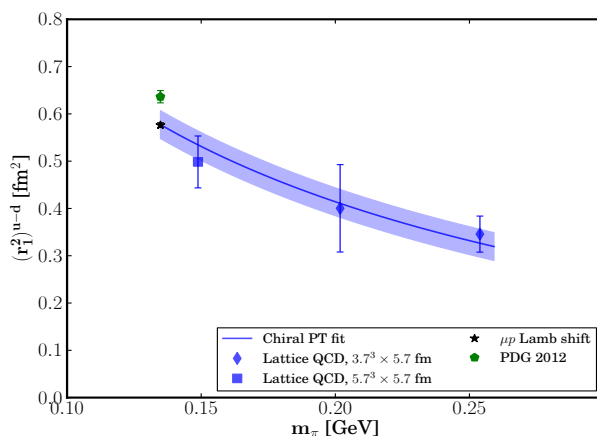
*Left: Four sectors of the HFT, each containing one 20-cm long "ladder" of Si chips of radius 2.5 cm and three ladders of chips of radius 8 cm; only the inner layer of ladders is visible. Right: Three sectors of the HFT were inserted into the STAR detector at RHIC on May 8; the inner radius of the STAR magnet (blue) is 82 cm.*

The next step for the PIXEL detector is to complete the construction of the full detector (ten sectors) and to re-install it for the 2014 RHIC gold run. At the same time, two more layers of silicon detectors (the IST and the SSD) will be installed; the full four-layer system will be called the Heavy Flavor Tracker (HFT).

## Proton radius computed from first principles

Obtaining the physical properties of hadrons from quantum chromodynamics (QCD), the fundamental theory of quarks and gluons, remains a significant challenge. Unlike quantum electrodynamics, for which the coupling constant is small, QCD cannot be treated perturbatively but requires computer simulations on a space-time lattice. To obtain realistic results the employed quark masses (and hence the resulting pion mass) must be light enough and that in turn requires sufficiently large lattices. In the past decade, lattice QCD has made tremendous progress, both through improved algorithms and due to more powerful computers, and calculations yielding the physical pion mass have started only recently.

One of the principal goals of lattice QCD is to reproduce the size and magnetic moment of the neutron and proton. Because the sizes of light baryons are very sensitive to the quark masses (as they decrease, the contribution of the surrounding pion cloud to the nucleon size increases rapidly), little progress had been made towards obtaining their physical sizes until recently. Working within the Lattice Hadron Physics collaboration (involving LBNL, MIT, and Jülich), Sergey Syritsyn, a postdoc in the LBNL Nuclear Theory Group, led an effort to extract the nucleon radius from lattice calculations having a pion mass as low as 150 MeV (only 10% higher than the physical value). Taking also careful account of systematic effects, Syritsyn and his collaborators have now succeeded in obtaining the long-sought agreement between QCD theory and experimental data for the nucleon radius.



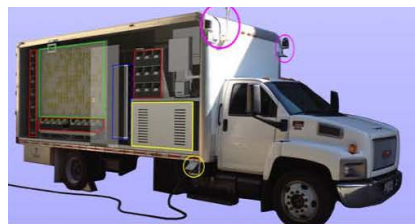
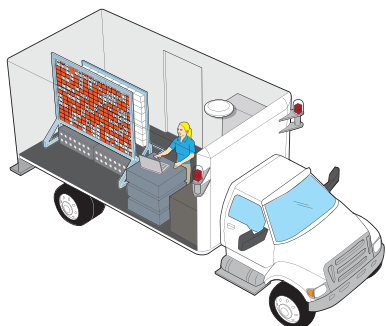
*The dependence of the so-called Dirac radius of the proton (which is based on the isovector density proportional to the difference between the u and d flavor density distributions) on the pion mass employed in the lattice QCD calculation. The experimental values are from the Particle Data Group and Lamb-shift measurements on muonic hydrogen.*

This theoretical advance is especially exciting because of the significant discrepancy between the experimental measurements of the proton radius by either electron-proton scattering or from muonic hydrogen. The current lattice QCD result favors the latter value, and its precision is already comparable to the difference between the two experiments values. With further improvements in calculational accuracy, lattice QCD will help to resolve this puzzle.

## Nuclear detection is becoming portable: RadMAP rollout

In mapping nuclear radiation backgrounds for nuclear security applications, special care is required when operating these systems on mobile platforms. Funded by a grant from the Domestic Nuclear Detection Office of the DHS, LBNL scientist and UCB professor Kai Vetter and a number of his colleagues, including postdocs and students, are carrying out a research project aimed at achieving a better understanding of the challenges and limitations associated with operating detector systems on a truck-based platform.

For this purpose, they have been using RadMAP, a Radiological Multi-sensor Analysis Platform designed to detect and localize anomalous radiation sources in crowded, real-life environments by filtering out naturally occurring radioactive materials as well as medical and industrial sources. The original MISTI truck was developed by the Naval Research Lab to search for gamma-ray sources; it consisted of high-purity germanium and sodium-iodide detectors, along with a GPS and side-looking visual and IR cameras. The NaI array has a coded lead mask placed in front to enable gamma-ray imaging. The additions made by the LBNL/UCB group include panoramic “ladybug” cameras, lidars (for distance ranging), a weather station, an internal high-precision navigation system, and a hyperspectral camera.



*RadMAP uses 24 high-purity germanium detectors to identify radioactive isotopes with high precision*

The large-area scintillator crystal detector array in combination with the random-patterned lead mask produces instantaneous gamma-ray images of any radioactive source present. Due to the changing location of the moving truck, these images can be combined to form a gamma-ray “movie” of the source. Digital video cameras create 3D images that are overlaid onto the gamma-ray images to help localize the radioactive source, supported by satellite for location and orientation maps from the rooftop GPS.

The RadMAP truck has been operated around the Bay Area for the past eighteen months, making more than 60 sampling trips and covering over 3,400 miles. The environments explored include metropolitan, suburban, and rural areas that contained commercial and industrial districts, military complexes, hospitals, both new and old roads (including dirt roads), bridges, mountains, and shorelines. Surveys are performed several times a week, each one covering a particular area with the goal of determining which environmental characteristics are the most important for determining the gamma-ray background of a given location. For example different neighborhoods of Oakland, such as Downtown and Jack London Square, have different background distributions. Once the system is provided with the basic character of the neighborhood, the detection parameters can be tuned appropriately, reducing the false positive rate by an appreciable amount.

## NSD participates in the *Visiting Faculty Program*

Professor Brooke Haag from Hartnell College in California is spending the summer at LBNL under the DOE sponsored *Visiting Faculty Program*, being hosted by the RNC program. NSD physicist Grazyna Odyniec is serving as her local mentor. They are collaborating on the analysis of experimental data taken with the STAR detector with the RHIC detector at BNL, specifically the rapidity dependence of the pion spectra resulting from Au+Al collisions at 3.0, 3.5 and 4.0 GeV per nucleon center-of-mass energy. They will subsequently write a manuscript for submission to Physical Review C; a draft for collaboration review is anticipated by the end of this summer's visit. The results will be presented by Professor Haag at the fall meeting of the Division of Nuclear Physics of the American Physical Society. They expect that their collaboration will continue over the course of several summers as there will be more data to analyze with the start of the fixed-target program at STAR.

Furthermore, a team from the University of Texas at El Paso, composed of Professor Jorge Lopez and undergraduate students Enrique Ramirez-Homs and Rodolfo Gonzalez, are visiting the Nuclear Theory Group under the Visiting Faculty Program, with senior physicist Jørgen Randrup serving as their mentor. They study the behavior of nuclear matter at subsaturation densities and with varying degrees of neutron excess in order to elucidate the role of isospin on the nuclear equation of state. In the summer of 2012, Professor Lopez also participated in the VFP and supported one-month visits of his student Enrique Ramirez-Homs (June) and physicist Dr. Claudio Dorso (July) from the University of Buenos Aires. Their initial investigations focused on the structure of the so-called nuclear pasta structures of relevance to stellar crusts and the resulting article in Physical Review C was spotlighted by the American Physical Society as exceptional research (see <http://physics.aps.org/synopsis-for/10.1103/PhysRevC.86.055805>).



*Visiting Faculty, Professor Brooke Haag (right), with her mentor, NSD physicist Grazyna Odyniec (left).*



*Senior physicist Jørgen Randrup (left) with Visiting Faculty Jorge Lopez and his students Enrique Ramirez-Homs and Rodolfo Gonzalez.*



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## NSD Fragments

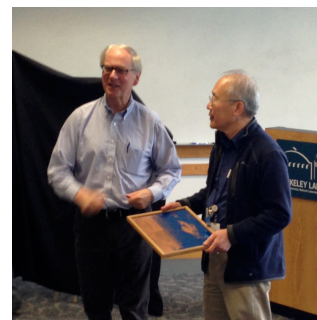
### Symposium held in honor of Hans Georg Ritter

NSD senior physicist **Hans Georg Ritter** was honored in a Symposium on *Collectivity in High-Energy Nuclear Collisions* on March 15 in Napa, California, following CPOD 2013 held there: the 8<sup>th</sup> International Workshop on Critical Point and Onset of Deconfinement. Since he came to LBNL in 1978, he has played a central role in the exploration of relativistic nuclear collisions, from the Bevalac to the LHC era, and he served as RNC Program Head until recently. James Symons recounted Hans Georg's career and many contributions, then five scientific talks followed by Declan Keane, Art Poskanzer, Grazyna Odyniec, and Kai Schweda. After the formal program, there was a dinner celebration, where Reinhard Stock gave a retrospective speech and many participants contributed entertaining reminiscences about Hans Georg.



### I-Yang Lee is honored at retirement

In May the NSD held a special celebration to honor Senior Physicist I-Yang Lee, who retired by the end of 2012 after more than 20 years at LBNL. After two years as a postdoc at the 88" Cyclotron, he went to ORNL for a decade but then returned to LBNL to help build the GAMMASPHERE detector. Over the past decade he has played the leading role in the advent and construction of the (now completed) GRETINA detector. I-Yang also served at Head of the Low-Energy Program for a number of years and he is highly respected throughout the community.



**Shushu Shi** joined the Relativistic Nuclear Collisions Program as a postdoc, coming from Central China Normal University; he will be working on HTF related software, calibration, and physics analysis.

*The NSD Newsletter is edited by Jørgen Randrup (JRandrup@LBL.gov) and issues are archived on the NSD home page: <https://commons.lbl.gov/display/NSD/home/>*